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ABSTRACT

The author argues that the input-output model of learning is inadequate for those who believe education is to produce persons who can solve problems in a particular area. He suggests that the act of learning be examined rather than the products of an educational experience. Piaget's mental-structures model of learning is then discussed along with his theory of types of mental structures that can exist at various times throughout the life of a person. The merits of several teaching procedures are reviewed and weighed.

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PIAGET'S THEORY OF ASSIMILATION AND CONCEPT LEARNING

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One result of higher education--perhaps the primary result--should be the development of the ability of a person to solve problems in a particular area of specialization. But solving a problem requires the problem solver to use the vocabulary, techniques, hardware, and other materials of the discipline involved. The problem facing higher education today is: what can students do in four academic years to learn how to solve problems in their major areas?

Do not interpret "solving problems" in a narrow, restricted sense. That phrase is meant to convey that the student has learned how to function in a particular area when solving problems in it. When a student solves a problem involving transistors, for example, that person uses the basic concepts of electricity as well as the modern technology surrounding the transistor. It is such inter-disciplinary functioning that is demanded by a professional in any field and what is meant here by "problem solving."

Earlier the point was made that solving a problem in a field required the problem solver to know the materials of the particular discipline involved. But how does one develop an understanding of the materials of a discipline? For that matter, how does one develop an understanding of (learn) anything?

The Input-Output Model. There are several educational theory bases that can be used to answer that question. The theory base which is accepted by the overwhelming majority of educational personnel is called by Piaget the "empty box" conception of the learner. (1) The empty-box theory confines its attention to the inputs (stimuli) given the learner, the observable output that person makes (responses) and then taking into account only the direct relationship between the input and output. This theory ignores any internal activity or mental growth that might have gone on between the input and the output. The

learner is indeed an empty box and only behaviors that are observable count as learning. This theory, according to Piaget (2), "deliberately thumbs its nose at all kinds of mental life ... and confines itself solely to behavior in its most material aspects.."

When the empty-box theory base is put into practice it involves telling the students what the instructor wants them to know and which he/she has assumed they do not know, asking them what they have been told, and assuming that the students' replies are evidence of what has been learned. Not infrequently, rather than telling the students what is to be learned, some device--a machine or an especially prepared book--leads them step by step through material they are to know. In this way the behavior of the student is to be altered and the degree of that alteration is judged because of performance on some device designed to determine how much of the material the student has "learned." Not infrequently, the measurement device asks the student questions and then asks him/her to select an answer from an array of possible answers provided. Frequently there is only one correct--or best--answer and each of the other statements is, supposedly, designed to appeal to some misunderstanding the learner has about the material which was to have been learned.

In the laboratory sciences, the empty-box theory base incorporates another dimension called laboratory. Often the student knew what was supposed to happen in the laboratory investigation before it was begun. The data were collected to affirm that what had been transmitted to the student by the printed page, the verbal lecture, or a program of some type was in fact true. Thus, for example, the student may have been informed that the amount of heat generated is proportional to the amount of energy expended and that the proportionality constant between those two factors is 4.18 Joules/calorie. The laboratory then provides an opportunity

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for the student to use apparatus to measure that proportionality constant. To insure that the output regarding the proportionality constant the student will make in the future will be correct, he/she is asked to calculate the percentage of error between the value found and the acceptable value. Not infrequently, if that percentage is too large, new data have to be collected and the constant calculated again. The empty-box theory base dictates that built into a learning system must be reward and punishment. Thus, if a pigeon does not peck a particular object enough times, it receives no food, and if the percentage of error between a calculated value for a constant and the standard value is too large, the student must collect more data and calculate again.

The laboratory in the empty-box theory base for education is mostly an extension of what the student has been told by a person or some device. Proponents of this educational theory base often cite great "content-understanding" gains made by students who have experienced the concepts in a particular field using material prepared on the "empty-box" model. These content-understanding gains, however, are determined by measuring how correctly the learner can reproduce what has been transmitted. Now if the goal of education--at any level--is to reproduce correctly what has been transmitted, then it goes without saying that a machine, lecture, television, or any number of devices can be used to fill the empty-box (inputs) and lead students to produce the correct response (outputs).

B. F. Skinner, Harvard psychologist, has been most active in promoting the type of education just described. Recently, Skinner expressed that (3) "Education is the art of passing on what others have learned." For those for whom education has the purpose stated by Skinner, the empty-box theory is completely adequate. For those, however, who believe that education is to produce persons who can solve problems in a particular area, the empty-box theory base is inadequate.

Instead of studying only the inputs and outputs of education, suppose that what happens between them became the subject of investigation. In other words, what type of picture evolves if the act of learning is examined rather than concentrating only upon the products (knowledge) of an educational experience?

The Mental-Structure Model. From birth, the human brain develops processes, according to Piaget's model, to use in dealing with incoming data from the

environment. As a person grows older, these processes become more and more complex. Piaget calls them mental structures, which he describes as systems of transformation. (4) In other words, throughout our lives we develop mental data-processing units which are unique and among which certain relationships exist. It is those mental processing units--or mental structures--and the relationships which exist between and among them that are used in problem solving.

According to the Piaget model (5), all knowledge begins with assimilation, which is the process by which an individual takes into his/her mental structures data from the environment and with which mental operations are performed. But in order to perform mental operations, a mental structure must be present to accommodate the incoming data. If only an incomplete structure, or no structure, exists, the incoming data have little or no meaning because they cannot be processed. It is this lack of the presence of a mental structure which has led Piaget to state that the input-output (stimulus-response) theory of learning is (6) "entirely incapable of explaining cognitive learning." He makes that statement because, according to his model, he is convinced that in order for an individual to make a response to a stimulus (7) "the response was there first. ... A stimulus is a stimulus only to the extent that it is significant, and it becomes significant only to the extent that there is a structure which permits its assimilation, a structure which can integrate this stimulus but which at the same time sets off the response."

When a structure is not adequate to permit assimilation, the learner is faced with a disturbing event or what Piaget calls disequilibrium. But structures continually move toward equilibrium. That is, the learner makes attempts to reduce the disequilibrium resulting from the inability to respond to the stimulus from the environment. In so doing, structures are altered, combined and/or constructed. The individual has undergone a process of self regulation or has moved toward a state of relative equilibrium by adjusting mental structures. When that happens, the structures become sharper and more clearly delineated than previously. "But the very sharpness points up inconsistencies and gaps in the structure that had never been salient before. Each equilibrium state therefore carries with it the seeds of its own destruction ..." (8) Thus the accommodation has led to a new state of disequilibrium.

This complete assimilation--disequilibrium--accommodation--equilibrium cycle represents not only learning but what Piaget calls the process of intellectual development. The whole end point of the process is the revision of mental structures which can now be used in problem solving or, said another way, processing incoming data from the environment. Assimilation is the root of the production of knowledge because it is through that process that disequilibrium is produced and while reaching equilibrium through accommodation new structures are built. In fact, Phillips states (9) "the process by which structures are revised is called equilibration."

The foregoing model has led Piaget to say (10): "A certain equilibrium between assimilation of objects to the subject's activity, and the accommodation of this activity to the object thus forms the point of departure of all knowledge ..." In other words, all knowledge must begin by an assimilation, disequilibrium, and accommodation. Said another way knowledge can be thought of as the product of the interaction between assimilation and accommodation.

Teaching and Mental Structures. The process of equilibration is, of course, the process that constructs and revises mental structure. There are, however, three other factors which influence the construction and/or revision process. Those factors are maturation, experience, and social transmission.

Maturation is, of course, related to the entire process of growth. Included in this factor is the growth and organic development of the nervous system with which we were born. This fact plays an indispensable role in structure building and cannot be ignored. In schools and colleges, however, there is little that can be done to regulate and/or simulate this factor.

Experience, however, is quite another matter. Schools and colleges can do much to provide experiences with the phenomena to be understood. The natural sciences are particularly fortunate because they can provide a student an extensive and deep experience with the materials of the discipline through the vehicle of laboratory experimentation. There is, however, a need to understand fully what Piaget means by the place of experimentation in structure building. He believes that (11) "an experiment not carried out by the individual himself with all freedom of initiative is by definition not an experiment but mere drill with no educational value." In other words, the measurement

of the mechanical equivalent of heat described earlier would definitely fall into what Piaget describes as "mere drill with no educational value."

What type of teaching procedure would Piaget probably endorse? To begin with, the notion of what is meant by assimilation must be thoroughly understood. Assimilation occurs when an individual thoroughly explores and interacts with the materials of the discipline that are to be used to develop understanding of a particular concept. The student must probe, disassemble, construct, interact and do all manner of activities with the materials. That person must in fact gain a thorough familiarity with what is to be learned in order to become thoroughly disequilibrated. Such disequilibration will occur, however, only if the learner has a thorough exploration experience.

At this point the student is in need of some type of organizing scheme in order to begin differentiating relevant from irrelevant data; that is, the learner needs to begin accommodating. That organizing scheme is, of course, the concept to be learned from the disequilibrating experience just had. The concept introduction (or conceptual invention) can be made by the instructor or the students but someone must intervene and introduce the concept.

At this point the learner has accommodated exploration findings to an organizing scheme, but a degree of disequilibrium still exists because the integration of the new structure into existing structures has not been completed. The student now needs to be faced with what can be discovered about the usefulness of the newly accommodated concept. In short, the student needs to ask himself/herself three accommodating questions:

1. What can be done now that could not be done before?
2. What is known now that was not known before?
3. What questions can be asked now that could not have been asked before?

The student needs a period of intensive concept implementation (or discovery) of the usefulness of the concept. This is accommodating but can and may (12) also be a period of assimilation for a new disequilibrium.

All the while exploration, concept introduction, and concept implementation are going on, the students must be experiencing social transmission, the last of the factors listed earlier. Social transmission means talking with one's fellow

students and the instructor, questioning what is being said, and interacting in every way possible with the environment. Sitting and listening to a lecture is not social transmission.

Types of Mental Structures. Structure building through the assimilation-disequilibrium-accommodation procedure will take place only if the data being received from the environment can be assimilated into existing structures or if those existing structures can be rearranged and/or used to construct new ones. Thus what the student is expected to assimilate must be at the same intellectual level as that student's mental structures.

For more than 50 years Piaget has collected data regarding the types of mental structures that can exist at various times throughout the life of a person. According to those data there are four types of mental structures. Each of these structure types represents what Piaget calls a stage of intellectual development. For most persons the first two stages have been completed by about seven years of age. The last two stages (the third and fourth stages) to develop, however, need to be of concern to all teachers from at least the second grade through college.

The third stage of intellectual development--which is indicative of the types of mental structures present--Piaget calls concrete operational. That name reflects that the student can do mental operations; that is, he/she can perform mental experiments. But those mental operations can be done only with data from concrete events, objects, and/or situations. In other words, what this student is asked to assimilate must come from reality. Reasoning in a hypothetical-deductive manner is beyond the capability of someone who uses concrete operations. In Piaget's words (12): "I call these concrete operations because they operate on objects and not yet on verbally expressed hypothesis." This type of thinker cannot assimilate and build mental structures if he/she does not have experiences that are inextricable from reality. Data (13) have shown that approximately 50% of entering college freshmen are functioning with mental structures which reflect concrete operational thought.

The student in the fourth stage of intellectual development has mental structures that enable him/her to think beyond present reality. This person (14) "forms theories about everything, delighting especially in the consideration of that which is not." The content of the thought is less important to this student than its form which reflects an "If ..., then ...,

therefore" type of reasoning. For that reason Piaget has named this stage of intellectual development "formal operational."

The formal thinker is the person who when attending a lecture assimilates the information and transforms it into operational structures. This person has the transformational system--the mental structures--to function in an abstract situation such as a lecture. Data are available (15), however, which show that these persons move more and more deeply into the formal reasoning stage more rapidly if the content to be learned is presented as exploration, concept introduction, and concept utilization.

Teaching Results. During the past few years three studies have been conducted at the Science Education Center, University of Oklahoma, that used Piaget's mental structures model as their theory base. Two of the studies concerned themselves with classroom teaching procedures and one focused its attention on evaluation.

Work done at Oklahoma City University with a general education course in physical science demonstrated that concentrating on providing students with a breadth of experience leads them to enter into the formal reasoning stage. (16) The Kenner-Paske study referenced earlier demonstrated that using the exploration, concept introduction, and concept implementation teaching procedure leads students to achieve higher scores on content examination than those students taught by the lecture-demonstration technique. In addition, those students who entered the lecture-demonstration course as concrete operational remained concrete operational while those who entered as formal operational became more formal. Students experiencing the exploration, concept introduction and concept implementation procedure and who were using concrete reasoning when entering the course, moved into higher levels of concrete thought or into the formal stage. Those students who entered the course reasoning formally moved more deeply into the formal reasoning stage. In other words, the group experiencing exploration, concept introduction, and concept implementation all moved upward toward, into, or more deeply into the formal stage during the course. The lecture-demonstration procedure seemed to benefit only the formal reasoning students. As was stated earlier, only the formal students possessed the transformational systems necessary to profit from abstract lectures. Even then, however, they did not reach the levels of content achievement that were as high as those students taught with the alternate procedure.

Does the type of content with which a concrete student is asked to interact make a difference in his achievement? Lawson and Renner used secondary school biology, chemistry and physics students to gather data to answer that question.(17) They found that the content concept taught in those courses could be divided into formal and concrete categories. They also found that while concrete-reasoning students do develop measurable understanding of concrete concepts, they do not develop measurable understanding of formal concepts. Formal-reasoning students, however, do develop measurable understanding of both concrete and formal concepts.

The research completed and that currently underway suggest that the mental-structure of Jean Piaget has much merit. Increased content understanding as well as student achievement of advanced levels of intellectual development are the outcome of using this model to construct instructional procedures. In all the research done which studies the teaching procedure inherent in Piaget's mental-structure model, the attitude of the student toward learning through that procedure has also been assessed. In all cases, about 90% of the students stated--anonymously--that they felt good about the discipline they were studying using exploration, concept introduction, and concept implementation. About the same percentage of students studying the same discipline utilizing the lecture-demonstration technique, voiced their disapproval of that teaching procedure. Just possibly the positive attitude students develop toward a discipline when experiencing the teaching procedure inherent in Piaget's mental-structure model (exploration, concept introduction, concept implementation) may be the most positive contribution that model can make to society.

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